Some Thoughts on Advanced Air Mobility and Artificial Intelligence



November 2026

Context and applications

Hello, everyone, and thank you for joining us. Today I'll talk about advanced air mobility and artificial intelligence. We'll start with the missions and operating challenges. Then we'll look at the aircraft platform, propulsion system, flight control, and intelligent piloting.

Our main theme is how these parts work together to support safe and efficient low-altitude operations. First, let's look at what advanced air mobility means.



Advanced Air Mobility (AAM)

Here, advanced air mobility, or AAM, is mainly about automated electric aircraft carrying people and goods in cities and remote areas. A familiar example is the electric vertical takeoff and landing aircraft, or eVTOL. Winged eVTOLs combine vertical flight with efficient cruise using wing lift.

Applications include urban and regional transport, logistics, sightseeing, and emergency services. AAM is also a system of systems: aircraft need vertiports, charging facilities, digital air traffic management, and an relevant regulatory framework. This wider system links aircraft technology to the low-altitude economy.

The next question is how to build this system in stages.

Aircraft Types

- electric vertical takeoff and landing aircraft (eVTOL)
- combining helicopter-like vertical flight with fixed-wing cruise efficiency

Applications

- Urban Air Mobility (UAM) and Regional Air Mobility (RAM)
- short-haul passenger services, sightseeing, on-demand logistics, emergency medical services and rescue.

System Characteristics

- vertiports
- charging facilities
- digital air traffic
- management networks
- regulatory frameworks.

AAM — Implementation Strategy

The approach here is to build the system in stages. Early operations use existing infrastructure and rules, while pilot programs build operating experience. That experience feeds back into new policies, certification practices, and eventually deployment.

Cooperation among industry, regulators, and infrastructure providers supports this process. The key link is between real operating data and the development of regulations.

Now, let's look at the challenges driving these changes.

Roadmap

- Begin operations at existing airports and heliports under current rules;
- Public – private R&D on low-altitude surveillance and communications;
- Build a new regulatory framework from operating experience;
- Transform the ecosystem: achieve standardized large-scale deployment.

Pilot Programs

- Joby plans to launch passenger services first in Texas;
- The core principle is to use real-world operating data to directly inform the FAA's final regulations.





Global Alignment & Legislation

- Joby: entered the fifth and final FAA certification stage;
- Harmonized standards: the FAA, Australia, Canada, New Zealand and the UK issued a joint certification roadmap to avoid duplicate reviews and enable multinational sales;

Challenges of Low-Altitude Aircraft

The low-altitude environment brings four connected challenges. These requirements help explain why different aircraft configurations are being developed.

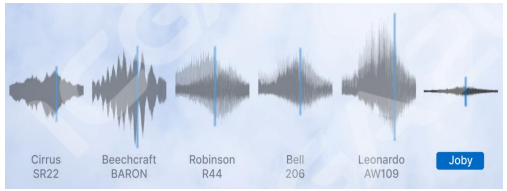
Low-Altitude Environment

- ✓ First, buildings and terrain create complex wind fields, so aircraft must handle gusts and sideslip.



Aircraft Noise

- ✓ Second, noise is especially important near homes and other sensitive areas.



Passenger Flight

- ✓ Third, passenger flights over populated areas have strict safety requirements.



Non-specialist Pilots

- ✓ Fourth, simplified vehicle operations, or SVO, aims to reduce operating complexity and training demands.



eVTOL Configurations

Three main configurations show different tradeoffs.

Multirotors have a simple structure, but their efficiency limits their range.

Lift-plus-cruise designs separate vertical lift from forward propulsion, but add weight and drag.

Tilting-propulsion designs combine vertical and forward thrust. They are flexible, but make the design and thrust-vector control more complex.

The current main research focus is on tiltrotor aircraft.

Joby



- Fully tilting propulsion
- 6 × 236 kW motors
- 4+1 seating layout
- Takeoff weight: 2.4 t
- Cruise: 241 km/h

Archer



- 6 tilt + 6 lift
- 12 × 125 kW motors
- 4+1 seating layout
- Takeoff weight: 3.2 t
- Cruise: 241 km/h

Lilium



- Tilting ducted-fan propulsion
- 36 × 45 kW motors
- 6+1 seating layout
- Takeoff weight: 3.1 t
- Cruise: 250 km/h

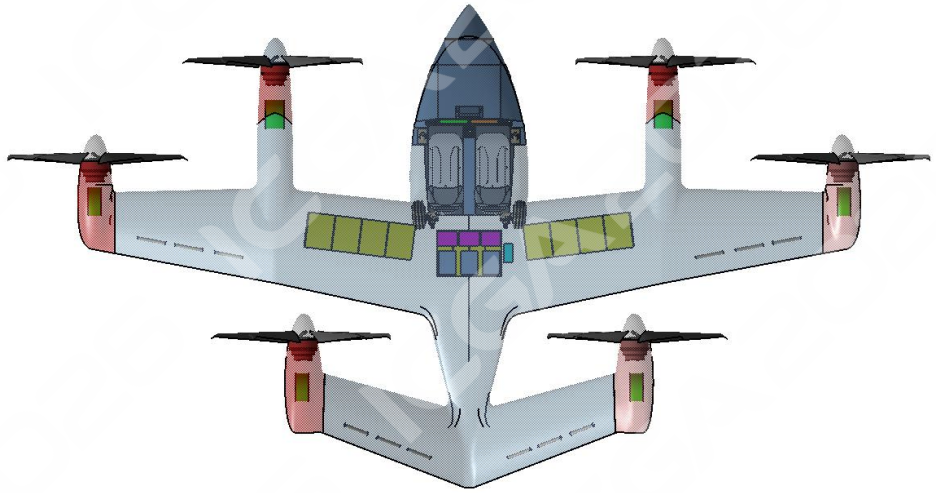


Part I Aircraft Platform

Aerodynamic Design

Let's take a reference aircraft configuration as an example. It uses a high wing and a V-tail to support efficient cruise. Its cruise lift-to-drag ratio target is at least fifteen. The control-surface layout uses several sets of ailerons and tail surfaces to provide redundancy. Wing geometry also sets where the propulsion units sit relative to the cabin and the center of gravity.

These choices link aerodynamic performance, control capability, and the physical layout. Next, we take a closer look at the propulsion layout.





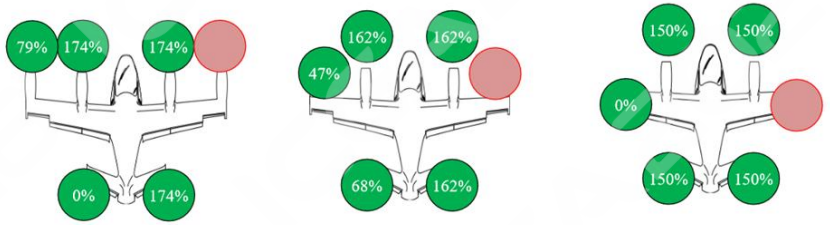
- Aerodynamic Configuration and Control Surface Layout:
  - A conventional high-wing, V-tail configuration provides higher cruise efficiency;
  - Wing and tail aerodynamic forces in cruise must meet static stability margin requirements;
  - Two sets of wing ailerons provide mutual redundancy;
  - Three sets of tail control surfaces provide mutual redundancy;
  - Tail control surfaces use dual attachment points。

Propulsion Layout

Propulsion layout is a key part of eVTOL design. The tilt-propeller concept shown here aims to avoid whirl flutter and other problems linked to tiltrotor configurations. The symmetric layout also aims to improve safety under fault conditions.

In hover, differential blade pitch and nacelle tilt generate control moments. In cruise, blade pitch and rotational speed are matched to airspeed to improve efficiency.

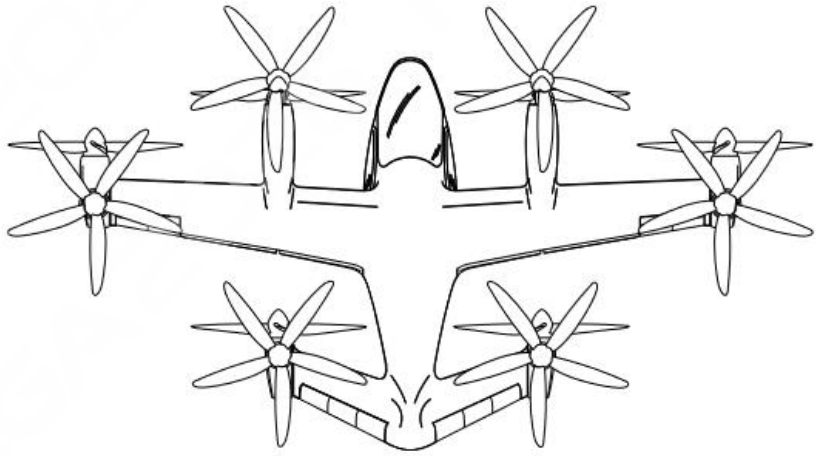
These propulsion choices must also be supported by a suitable structural design.











Structural Design

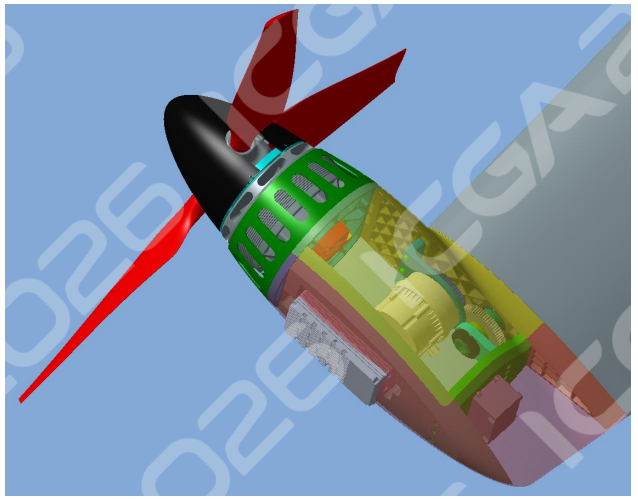
Structural design balances the airframe mass target with maneuver, gust, and landing loads. The stated targets include structural mass no more than twenty-five percent of total aircraft mass. The reference layout combines integral wing and tail structures with clearly defined fuselage interfaces.

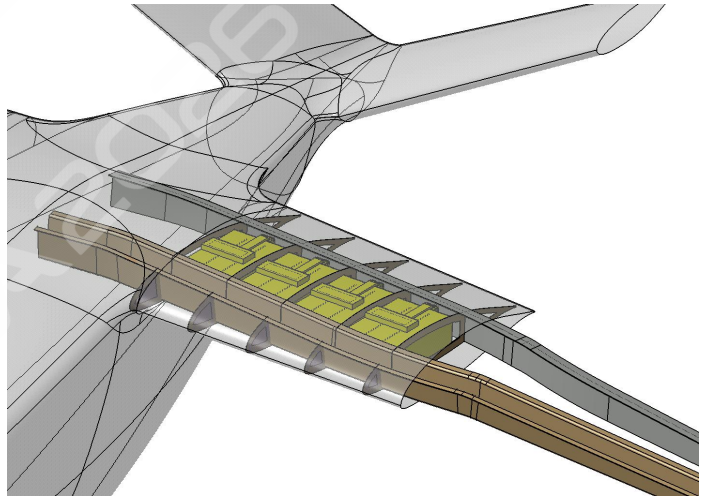
We now move from the airframe to propeller design.

❑ Strength and Load Analysis

- Separation interfaces for the main fuselage, one-piece wing and one-piece tail
- Wing structure uses integrally molded hat-section and J-section spars
- Fuselage uses dual ring frames, multiple longerons and separate left/right halves
- Tail uses integrally molded twin C-section spars







Propeller Design

Propeller design directly links flight efficiency and noise. Here, acoustic performance comes first, followed by hover efficiency and then cruise efficiency. Testing is the main development method, supported by computational fluid dynamics.

The design separates constraints from variables. Constraints include radius, blade count, and required thrust. Variables include chord distribution, rotational speed, tip shape, and airfoil. These variables are adjusted within the mission requirements.

Next, we look at the noise verification results.

Design Constraints:

1. Propeller radius
2. Blade count
3. Target hover thrust
4. Cruise thrust/speed targets

Design Variables:

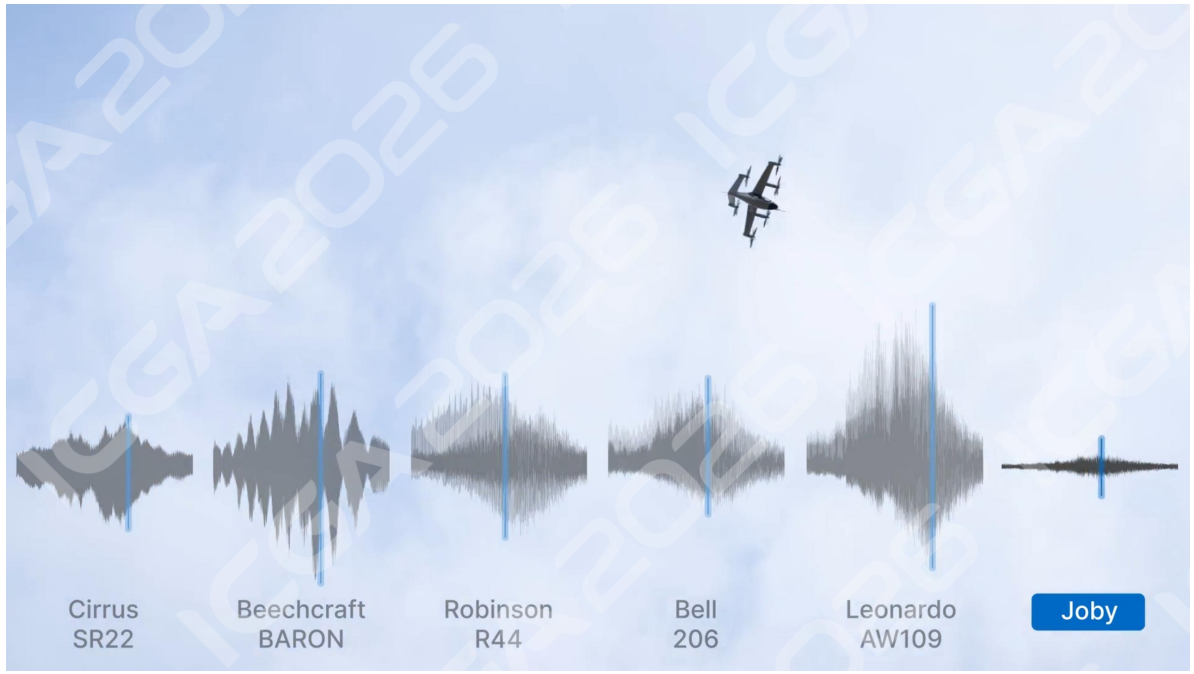
1. Blade chord distribution;
2. Hover rotational speed;
3. Cruise rotational speed;
4. Blade tip shape;

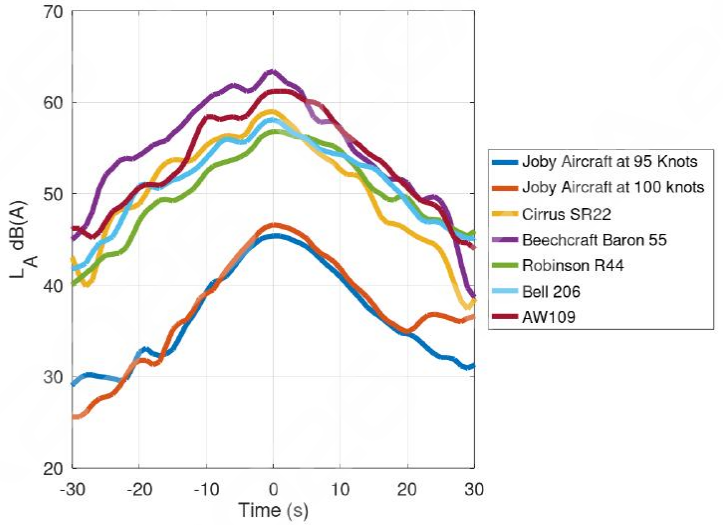




Noise Control

- The relevant test results link propeller optimization to lower noise levels. The results show that acoustic perfomance should be considered together with hover and cruise efficiency in the design process. Sound levels also depend on flight conditions and measurement position. That leads us to the propulsion system.





Aircraft	Airspeed	Airspeed	$L_{A,S,max}$
Joby Aircraft	95 knots	49 m/s	45 dB(A)
Joby Aircraft	100 knots	51 m/s	46 dB(A)
Cirrus SR22	100 knots	51 m/s	59 dB(A)
Beechcraft Baron 55	100 knots	51 m/s	63 dB(A)
Leonardo AW109	100 knots	51 m/s	61 dB(A)
Bell 206	100 knots	51 m/s	58 dB(A)
Robinson R44	100 knots	51 m/s	57 dB(A)



Part II Propulsion System

Propulsion System

The propulsion system brings three functions together. The battery system supplies energy. The motor converts electrical energy into mechanical energy, and motor control coordinates speed, torque, and dynamic response. Together, these functions support vertical flight and cruise.

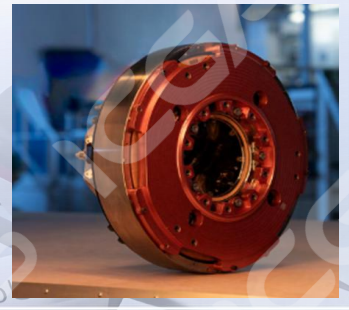
The key is coordination: cells, cooling, wiring, motors, and controllers must work as a system. We begin with the cells.



Battery System

Power | Sustained Energy

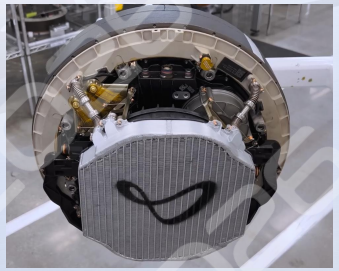
- Components: Cells, battery packs, BMS, cooling system, wiring harnesses, etc.
- Function: Store and supply electrical energy
- Type: Ternary lithium-ion batteries



Motor System

Thrust | Attitude Control

- Components: Drive motor and reduction gearbox
- Function: Convert electrical to mechanical energy to drive the propeller
- Types: Radial-flux and axial-flux motors



Motor Control System

Real-Time Dynamic Response

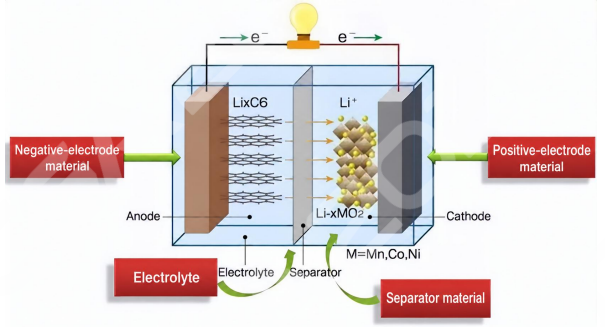
- Components: Digital control and power output stages
- Functions: Efficient motor speed/torque control, system monitoring, coordinated energy allocation
- Challenges: Better control, higher power density, adaptation to complex operating environments

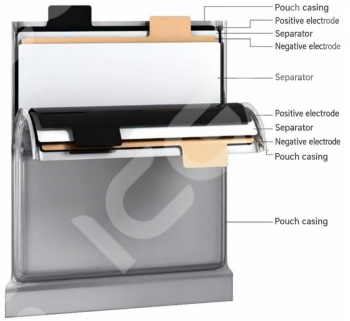
Battery System — Cells

At the cell level, we balance specific energy, power capability, and safety. Specific energy means the energy stored per unit mass. We choose materials and cell formats with these objectives. These choices cover electrode, electrolyte, separator, and casing.

The cell technologies discussed here include high-nickel NCM and pouch cells. Development directions include silicon-based and solid-state .

The next step is to turn cells into a complete battery pack.





Core Parts

Cathode Materials

High-nickel ternary | High energy density | Mainstream for eVTOL

Lithium Iron Phosphate

Low cost | Energy storage & budget vehicles

Anode Materials

Graphite

Commercial mainstream | Low Si content for eVTOL

Silicon–Carbon Composites

High specific energy | eVTOL R&D

Electrolyte

Liquid

Mainstream LiPF6 | Low specific energy

Semi-solid / Solid-state

eVTOL adaptation | Safety improvements

Separator

Materials

PE/PP base film | Ceramic coating

Technology Trends

Ultrathin | High porosity

Cell Format

Cylindrical

Mature process | High consistency

Pouch

Flexible geometry | High energy, low weight

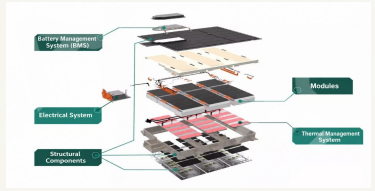
Battery System — Pack Assembly

Pack Components

A battery pack must do more than connect cells. It brings together structural protection, electrical connections, monitoring, cooling, and ease of maintenance.

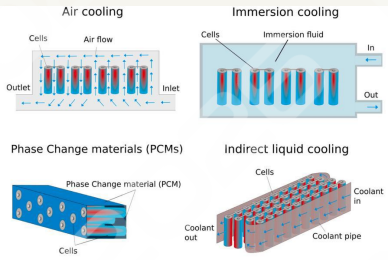
Series and parallel connections provide the required electrical characteristics.

The casing and thermal system address mechanical and temperature conditions.





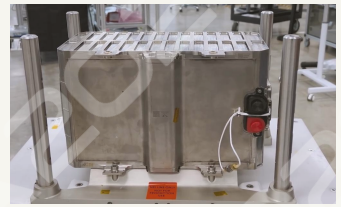


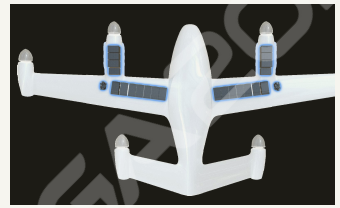


Pack Integration

Battery placement is also closely linked to aircraft integration.

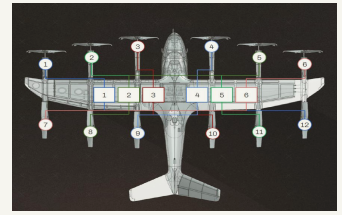
The battery management system coordinates the monitoring and protection functions.





JOBY
Battery Modules & Layout



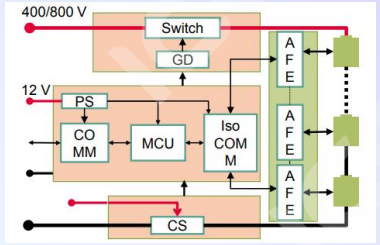


Battery System — BMS Functions

The battery management system, or BMS, uses measured battery information to make operating decisions. Its main functions include voltage and temperature monitoring, current measurement, cell balancing, protection, and charge or discharge control. State of charge tells us how much charge remains. State of health tells us the battery's condition. Data storage and communication support these functions.

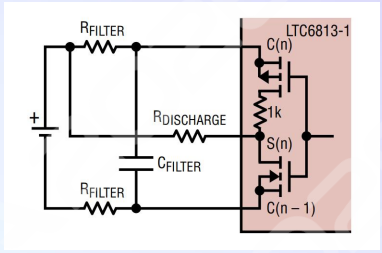
Development directions include active balancing, wireless data transmission, and additional sensing for thermal-runaway protection. Now we move from energy management to the propulsion motor.

Battery Protection



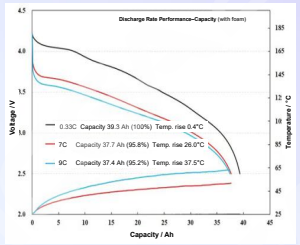
- Over/undervoltage protection
- Surge current protection
- Short-circuit protection
- Thermal management

Cell Monitor & Balance



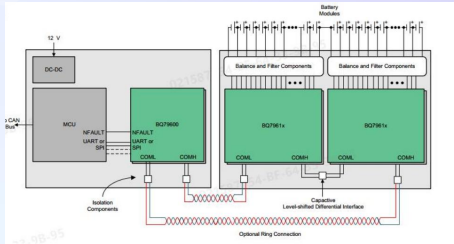
- Cell voltage sensing
- Cell current sensing
- Cell temperature sensing
- Cell voltage balancing

Battery Monitor & Control



- State of charge (SOC) estimation
- State of health (SOH) estimation
- Battery temperature control
- Battery charge/discharge control

Data Storage & Comms



- Data storage
- Daisy-chain communication
- Software over-the-air (SOTA) updates
- Functional safety

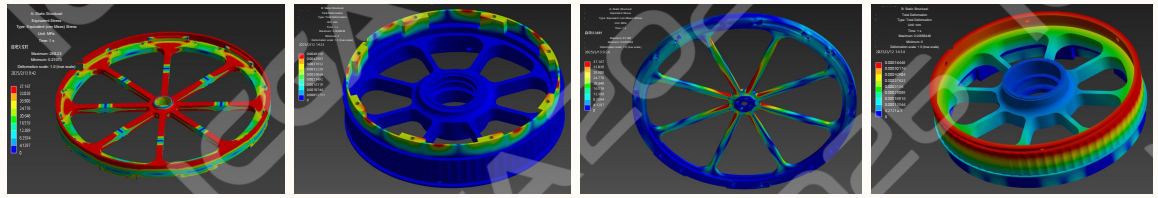
Propulsion Motor

The propulsion motor must balance structural strength, weight, torque density, and efficiency. Low rotational speed with high torque is especially important in this design. This also makes copper losses and cooling critical engineering concerns. The key technologies are compact structures, dual three-phase electromagnetic design, flat-wire windings, and efficient liquid cooling.

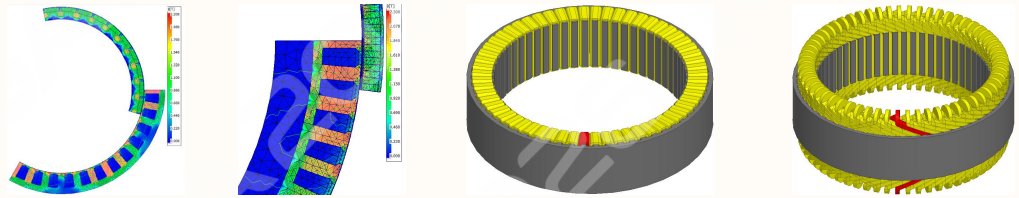
Next, we look at the mechanism that changes the direction of thrust.

Key Technologies

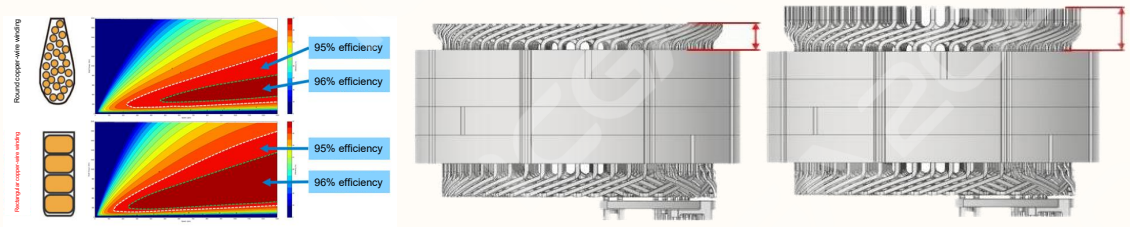
- Compact, high-strength motor structural design



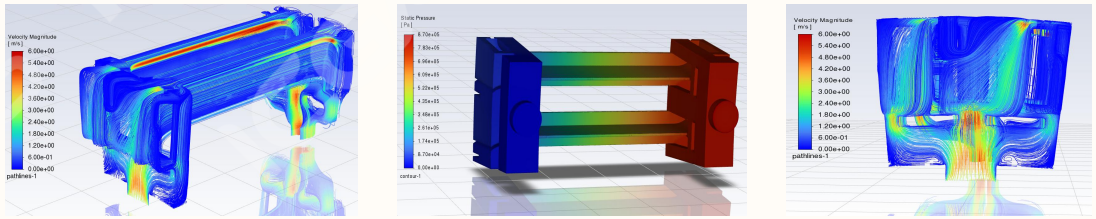
- Dual 3-phase EM optimization: fault tolerance & high torque density



- Rectangular-wire windings: high slot fill, short ends, fewer welds



- Efficient, lightweight liquid cooling & low-resistance channel machining



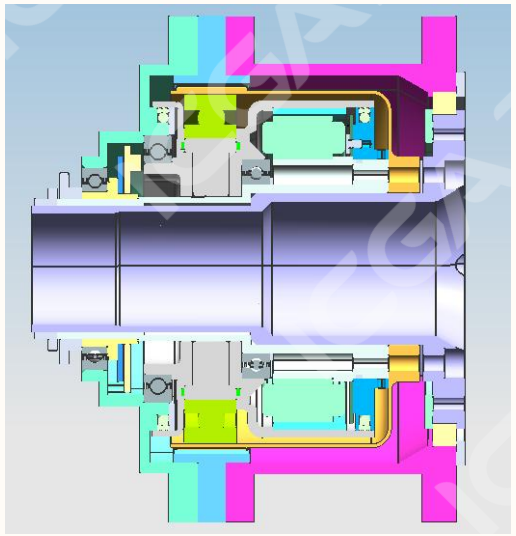
Tilt Mechanism

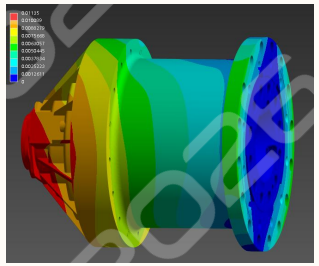
The tilt mechanism connects the nacelle to the airframe. It must support the nacelle and accurately control its position under strict weight and size constraints.

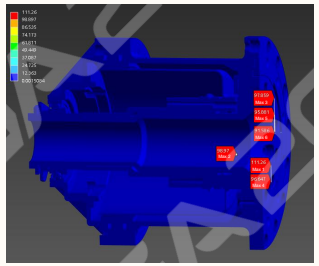
Therefore, the two focuses are a lightweight load-bearing structure, and precise synchronization during both motion and steady-state conditions. Motor control must coordinate these mechanical functions.

Key Technologies

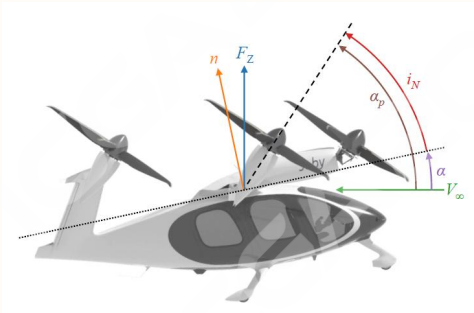
- Lightweight, high-load-capacity tilt actuator structures

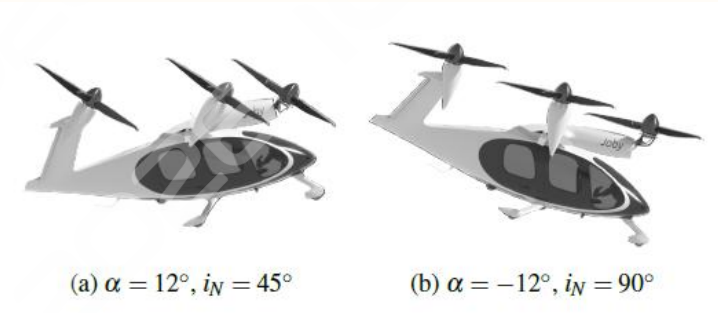


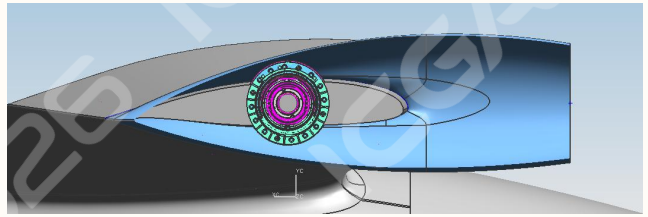


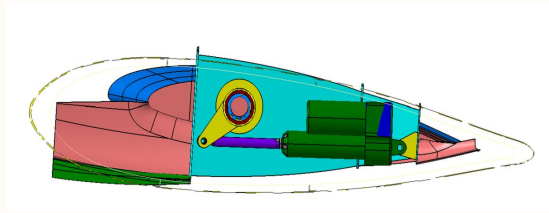


- High-precision dynamic/static tilt synchronization control









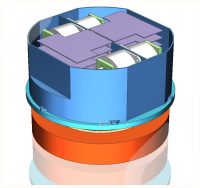
Motor Control System

Motor control brings propulsion, tilt, pitch, and cooling functions together. The challenge is to control the system efficiently throughout the flight. At the same time, we need to manage the electrical interactions between high-power switching devices.

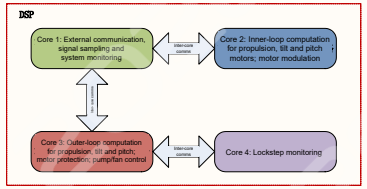
Here, areas for design and optimization include device matching, parasitic impedance balancing, gate-drive synchronization, and carrier-phase techniques. These control functions then become part of the integrated propulsion system.

Key Technologies

High-power-density integrated control

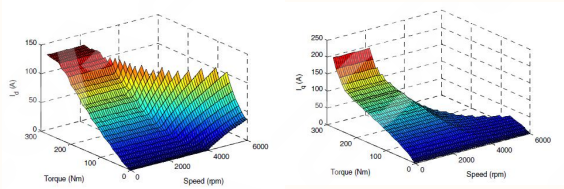


Highly integrated motor control



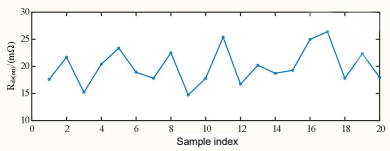
Task allocation and scheduling

Efficient control across the full flight profile

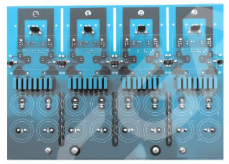


Optimization + accurate copper/iron loss estimation + all-condition optimization to minimize copper and iron losses

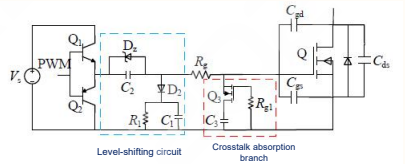
Parallel power devices and crosstalk suppression



Combine closely matched devices
Reduce variation and mismatch

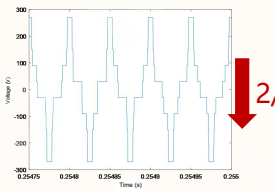


Balance parasitic impedances
Balance stress; synchronize gate drives

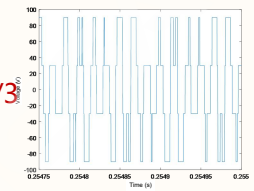


Absorb/divert crosstalk current to suppress spikes and improve immunity

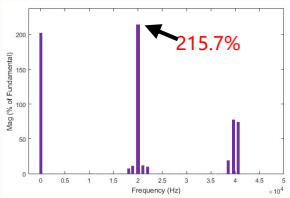
Active EMI suppression for high-voltage, high-power propulsion



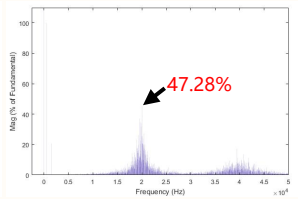
Common-mode voltage without carrier phase shifting



Common-mode voltage with carrier phase shifting



Conventional voltage spectrum



Spread-spectrum PWM voltage spectrum

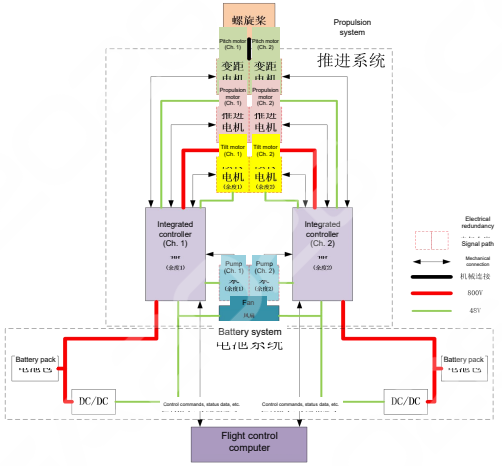
Propulsion System Integration

Integration has two sides. On the mechanical side, propulsion, tilt, pitch, and cooling are combined in a compact assembly. On the electrical side, it uses two physically separate electrical channels, with communication and monitoring between them.

This tight integration increases coupling between the mechanical, electrical, and fluid systems. We now move from propulsion integration to aircraft flight control.



Propulsion Physical Integration



Propulsion Electrical Integration

Vertical Structural Integration

- **Propulsion, tilt and pitch: structural integration**
- **Propulsion motor, controller and cooling: system integration**
- **Cooling system integrates pumps, fans and radiators**

Top-Level Electrical Integration

- **Propulsion, tilt, pitch and coolant-pump functions share four-in-one control**
- **Electrical dual redundancy with physical separation improves safety**



Part III Flight Control System

Flight Control Architecture

The flight-control architecture brings together three key focuses. Distributed vectored thrust provides control capability across the flight envelope. Simplified Vehicle Operations, or SVO, aims for consistent control methods that reduce the pilot's workload. Low rotational speed and high torque support the propulsion design's noise-control goal.

These key focuses have to work together. The pilot can say how they want the aircraft to move. The control functions work out how to achieve this. This depends on a suitable full-aircraft dynamics model.

Distributed Vectored Thrust

- Distributed propulsion increases full-envelope thrust margin, control authority and strong-crosswind attitude control
- In every mode, distributed vectored thrust must enable safe flight after one failure, ensuring aircraft safety



Simplified Vehicle Operations (SVO) Design

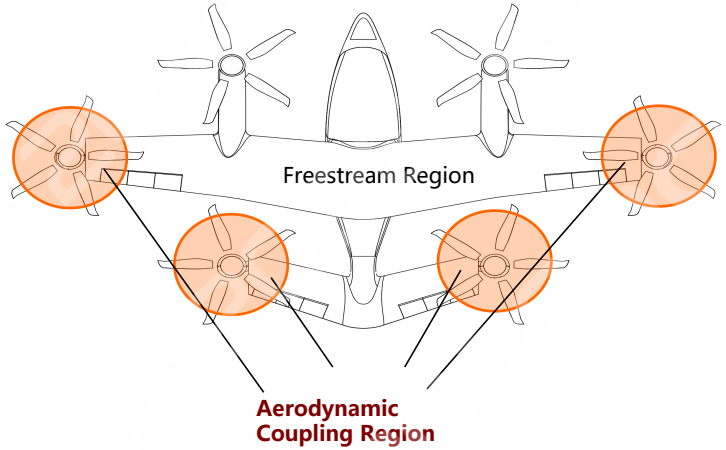
- Pilot commands evolve from direct control-surface inputs to attitude-angle control, then simplify further to direct velocity-vector control, reducing demands on pilot knowledge and response
- SVO requires full-envelope coverage with uniform control methods and control laws, reducing flight-control mode switching and improving safety

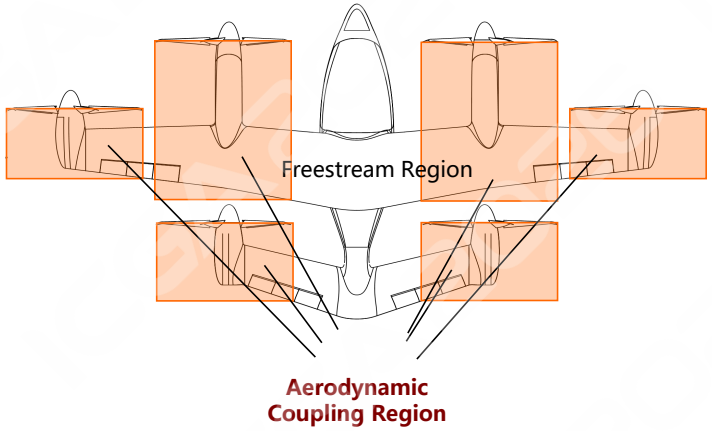
Low-RPM, High-Torque Propulsion

- Phase control is key to low-noise distributed propulsion: precisely control each propeller's phase without impairing handling
- Lower tip speed is the most effective propeller-noise reduction, requiring motors



Full-Tiltrotor Dynamics Modeling





Aerodynamic Model:

$$\begin{cases} D = D_{slip} + D_{free} \\ Y = Y_{slip} + Y_{free} \\ L = L_{slip} + L_{free} \end{cases} \qquad \begin{cases} l = l_{slip} + l_{free} \\ m = m_{slip} + m_{free} \\ n = n_{slip} + n_{free} \end{cases}$$

Slipstream:

$$\begin{cases} V_s = \sqrt{(u + V_i\cos\varphi)^2 + v^2 + (w - V_i\sin\varphi)^2} \\ \alpha_s = \tan^{-1}\dfrac{w - V_i\sin\varphi}{u + V_i\cos\varphi} \\ \beta_s = \tan^{-1}\dfrac{v}{\sqrt{(u + V_i\cos\varphi)^2 + (w - V_i\sin\varphi)^2}} \end{cases}$$

A full-aircraft dynamics model must capture how the airframe and distributed propulsion interact. The difficult areas include low-speed aerodynamics, propulsor slipstreams, and transitions between rotor-borne and wing-borne flight. As the nacelles tilt, we must consider aerodynamic interactions, along with the aircraft's mass distribution and rotational inertia.

Wind-tunnel tests and computational fluid dynamics refine the aerodynamic model. Vehicle-based ground tests refine the propulsion model. The next challenge is control law design under multiple constraints.

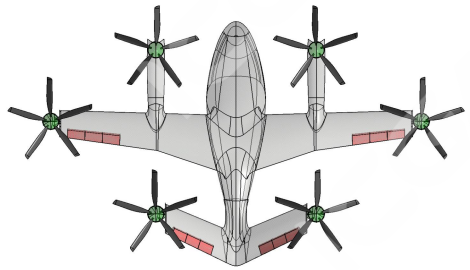
Control Law Design

A tiltrotor combines helicopter and fixed-wing characteristics. Its controls therefore have to work together across very different flight conditions. This requires three connected tasks: allocating control effort, planning transitions between flight modes, and protecting the flight envelope.

Control effectiveness changes with speed. So transition planning considers wing lift, stall, and rotor power together. We must then assess performance through typical flight tasks.

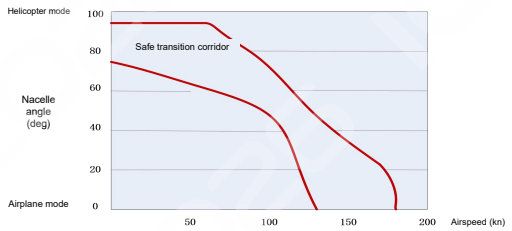
Distributed Vectored Thrust

- 6 DOF, 30 control inputs; non-unique trim solutions and many control-surface combinations
- Design dynamic allocation using a flight-performance database, accounting for control-effectiveness nonlinearity



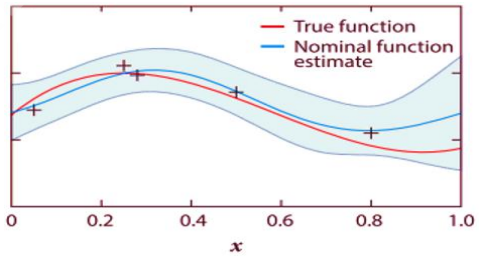
Simplified Vehicle Operations (SVO) Design

- Within corridor boundaries defined by multiple constraints, automatically optimize a nominal trajectory with adequate safety margins
- Low speed: Apply strict stall-angle-of-attack and wing-lift constraints



Low-RPM, High-Torque Propulsion

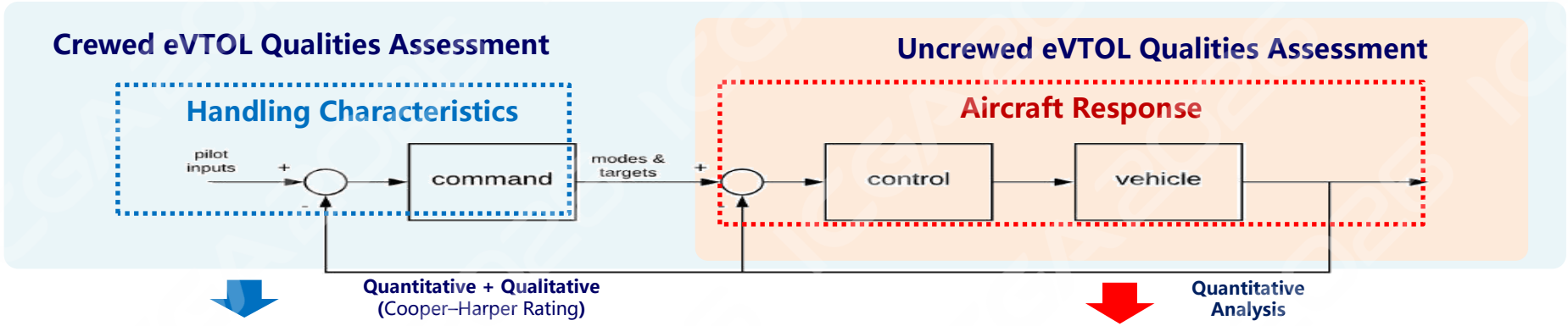
- Support variable rotor speed in coordinated control and full-envelope, multimode flight-envelope protection
- Integrate flight/thrust management to satisfy multiple aircraft and engine safety constraints



Flying-Qualities Assessment

Flying qualities describe how the aircraft responds during a task. Assessment must fit the mission, because eVTOL aircraft differ in size, weight, and configuration. Hover, transition, and forward flight place different demands on the system. For crewed aircraft, assessment combines measured responses with pilot evaluations. For uncrewed aircraft, assessment focuses on quantitative aircraft response.

Criteria for helicopters, tiltrotors, and fixed-wing aircraft provide references for the relevant flight phases. These assessments also lead us into the wider discussion of airworthiness.



Handling Qualities Task Elements (HQTE)

U.S. Military Rotorcraft ADS-33E MTE

(Released in 2000)

Hover Low Spd.

+

U.S. Military High-Speed Rotorcraft MTE

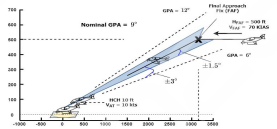
Transition Forward Flight

+

Urban Air Mobility (UAM) Mission

(FAA Program Research)

Specific Cases



Frequency- and Time-Domain Assessment

◆ Hover	Use quantitative criteria from existing helicopter flying-qualities standards
◆ Transition	Use quantitative tiltrotor criteria for the V-22 Osprey and civil BA609
◆ Forward Flight	Use existing quantitative fixed-wing flying-qualities criteria

Airworthiness Considerations

We can look at airworthiness at three levels: the aircraft, its systems, and the hardware and software within them. Technical references cover different parts of this structure, including system development, electronic hardware, software, and environmental testing. They help us organize the safety and compliance questions that need evidence. For AI, the focus is on auditable learning data and repeatable verification.

We now turn to intelligent piloting.

Aircraft/System Airworthiness Basics

- **Aircraft type airworthiness:** CCAR23 fixed-wing; CCAR27 helicopters; CCAR33 engines; CCAR35 propellers; CCAR36 noise
- **Airborne system airworthiness:** AC20-174 civil aircraft system development; ACXX-1309 system safety design and analysis; SAE ARP4754B/4761A
- **Component airworthiness:** RTCA/DO-254 airborne electronic hardware; -178C airborne software; -297 IMA development guidance; -331 model-based software development and verification; -160G airborne-equipment environmental testing

eVTOL vs. Existing Requirements

	eVTOL	Existing Rules
Operating Area	Suburban housing areas	Away from housing areas
Noise Limits	≤ Car noise (strict limit)	Less Stringent
Flight Altitude	Low altitude (~600 m)	High altitude (6,000 m+)
Airspace Challenges	Many obstacles; complex weather	Simple setting; few obstacles
Operating Mode	Highly automated (SVO)	Mainly manual control

eVTOL Aircraft/Systems Airworthiness References

- **Aircraft type airworthiness**: EASA VTOL SC/MOC; Joby/Archer SC; AC21.17-4 Powered-lift TC
- **Propulsion motor and drive airworthiness**: Guidelines for Drafting Special Conditions for Electric Propulsion Systems
- **Battery system airworthiness**: EASA MOC3 battery compliance methods; VTOLWG 112 VTOL SG-1 electric propulsion batteries; RTCA/DO-311A minimum operational performance standards for battery systems; WG 116 high-voltage systems and components
- **Airworthiness of AI applications :** ATC, airborne obstacle detection and avoidance, long-range airfield recognition for approach and landing, fully autonomous visual navigation.



Part IV Intelligent Piloting

Intelligent Piloting

Three main needs drive the development of intelligent piloting. The first is the staffing and cost challenge as operations grow. The second is the difficulty of sensing a complex urban environment. The third is coordinating aircraft as traffic becomes busier.

Together, these needs show why intelligent assistance matters. Intelligent piloting is the only path from eVTOL flight capability to commercial operation. These needs must be turned into specific system functions.

High Costs Drive Simplified/Uncrewed Operations

- Boeing forecasts: 660,000 new pilots needed globally over 20 years
- Labor accounts for 30–40% of helicopter operating costs



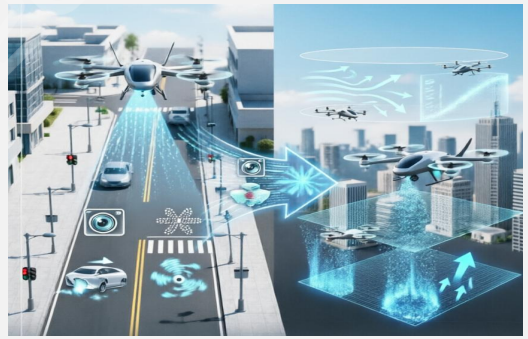
Complex Urban Low-Altitude Environments

- Urban-canyon multipath effects → Visual disorientation
- Rain/fog/low light → Human visual range <50 m; glare → <10 m
- Complex environments → Crosswind and other UAM challenges



High-Density Flight Scenarios

- High-density flight: 5 eVTOLs per 1 km^2
- Civil aviation safety standard: ≤10^{-9} fatal failures per flight hour
- Pilots plus hardware redundancy alone cannot meet certification requirements;



Intelligent Piloting Functions

The functions fall into three groups: navigation and route planning, obstacle avoidance and autonomous takeoff and landing, and enhanced vision.

Navigation combines satellite and inertial information with visual positioning. Obstacle avoidance uses information about detected obstacles to plan paths the aircraft can follow. Enhanced vision improves images and presents obstacles, landing areas, and risks to the display or control system.

These functions are built on visual perception and high-performance computing.

Intelligent Navigation



Intelligent Avoidance

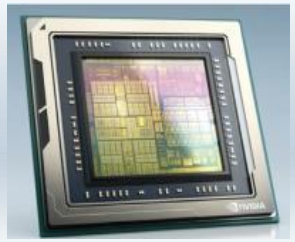


Enhanced Vision



Perception and Computing

- "Understand" the world: sensors, perception tasks, and scenario-specific environments
- Computing: use perception results for localization, prediction, planning, and control
- Compute capability: chips, architecture, operating systems, power, and cooling

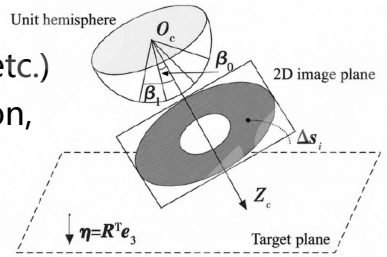


Visual Perception

Visual Perception

Image processing and **feature extraction**:

- Image denoising, enhancement, and correction
- Feature-point detection (SIFT, ORB, FAST, etc.)
- Image segmentation and object recognition, YOLO, etc.)



Visual information processing:

- Deep-learning-based object detection and classification
- Semantic segmentation, scene understanding, etc.

Environment Modeling

Data fusion:

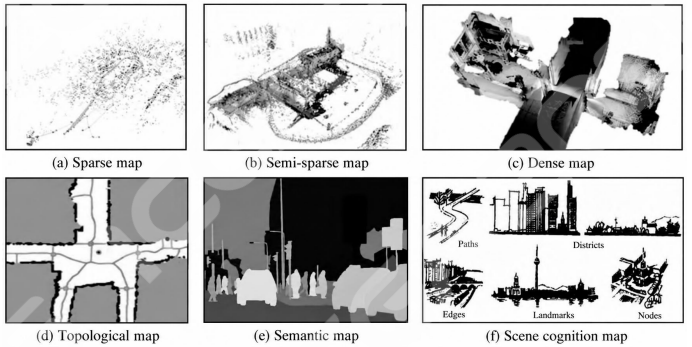
- Multisensor fusion: vision, LiDAR, GPS, IMU, etc.

3D map construction:

- 6 common map models

Map updates and maintenance:

- Real-time map data updates
- Intelligent static/dynamic map fusion and management



Visual perception and environment modeling have different but connected roles. The system cleans up images, extracts features, and recognizes objects. It then combines information from several sensors into maps, which must be updated as the surroundings change.

These steps support these applications: navigation, autonomous takeoff and landing, and obstacle avoidance. These functions place high demands on the computing platform.

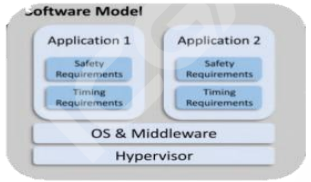
High-performance Computing

Four areas connect AI functions to a practical computing platform: the operating system, performance assessment, different types of processors, and engineering integration. To understand computing performance figures, we need to consider the workload, software, power use, and cooling.

Engineering work focuses on how the platform supports the perception and decision-making functions. Now let's move to the closing remarks.

Container-Based Operating System

- Linux Operating System
- Supports Linux containers
- Containers are mutually isolated
- Container manager controls subcontainers



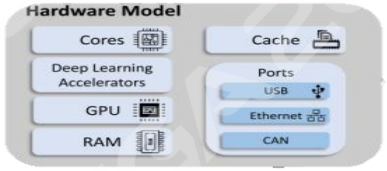
AI Hardware Performance Assessment

- MLPerf Benchmark
- Standardized AI hardware performance testing and assessment
- AI models include RetinaNet, 3D U-Net, RNN-T, BERT, etc.
- Suitable for GPU and AI-chip testing

MLPerf

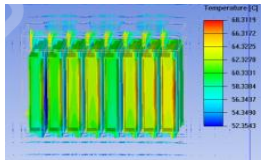
General-Purpose Computing Platform

- CPU+GPU+SOC+FPGA
- Compute performance: ≥100 TFLOPS; data bandwidth: ≥1 Gbps
- Processing nodes: ≥7



SWaP Design Optimization

- High system power (360 W)
- Forced-air-cooled chassis
- Optimized cooling-fin spacing
- Vapor chambers / thermal grease



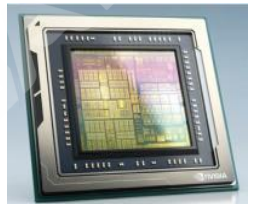
Research Progress



eHPC-4
2022
30 TFLOPS



eHPC-8
2023
250 TFLOPS



eSC
(Super computer)
2024
1000 TFLOPS

Closing Remarks

Advanced Air Mobility brings together the aircraft platform, propulsion system, flight control, and intelligent piloting in a connected engineering challenge. Across these areas, we have focused on safety, reliability, and operation in complex environments.

Artificial intelligence is becoming a foundational enabling technology for AAM, supporting its scalability, autonomy, and economic viability.

Our goal is to make safe low-altitude services accessible to more people. Thank you for your attention.